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*Original Article*

# Stability of the Emulsion and Physicochemical Characteristics of Low- fat on Storage Time Using Hydroxypropyl Distarch Phosphate (E1442) and Xantan Gum as Fat Replacers

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## ABSTRACT

**Background and Objectives:** In this study, think over to collected and classification of food science engineering comprehensive datas about each experiment with expanded results. Moreover, in most of discussion added extra reasons to each phenomenon. The aim of the present study was assesse of E1442 with xantan gum as fat replacers of carbohydrate base on physicochemical and sensory evaluation of low-fat mayonnaise.

**Materials and Methods:** Four treatments were designed with 25, 50 and 75% replacements of the control sample with traditional mayonnaise (65% oil content).

**Results:** On emulsion stability of the samples, results were significant ($P \leq 0.05$) for the storage time. In addition, physicochemical results showed that low fat mayonnaise prepared with present fat replacers of carbohydrate base (E1442 and xanthan gum) access to highest amounts in ash and moisture and also lowest in fat content and calorie. pH and acidification were in ranges of (3.70-3.73) and (1.12-1.13) respectively. Low fat mayonnaise samples were higher than apparent viscosity than that control sample was. Sensory evaluation results showed that fat with 0.25% concentration were at highest in overall acceptability and intent to purchase which are the most important factors in marketing.

**Conclusions:** In general, result demonstrated that low-fat mayonnaise prepared with 25% of E1442 with xantan gum was an appropriate treatment with highest scores in most of the experiments.

**Keywords:** Mayonnaise, Fat replacer, Emulsion, Xantan Gum, E1442

## Introduction

Fat is one of the easy access source of energy for daily activities. Fats and lipids are vital with essential effects on human metabolism. However, consuming too much inappropriate types of fats can lead to weight gain or obesity, hypertension and diabetes. When comparing between advantages and disadvantages of the fats, weight, caloric intake and health goals and concerns must be considered. Consumption of 20-30 gr of saturated fats a day is recommended. Mayonnaise is a famous oil in water emulsion system with thick creamy texture that contains vegetable oils like soya such as sunflower oils, vinegar (acetic acid), egg yolk (containnings a natural emulsifier /or egg lecithin) salt, sugar and some of common spices such as red and black peppers in combination with artificial or natural emulsifiers and thickening agents (modified starch, guar gum and xanthan gum). Traditional mayonnaise is prepared with 70-80% of the fats in formulations. Based on the consumers' behavior and demand, a majority of the mayonnaise products on the market are low-fat mayonnaises. Low-fat mayonnaises include fat contents of 20-40 %. Having substantially lower fat content fat-replacers (known as emulsifying and thickening agents) are widely used to create the characteristic thick and creamy consistency of mayonnaises with lower fats. Nevertheless, full fat mayonnaise prepared with high levels of unsaturated fats can cause pandemic diseases such as cardiovascular (CVDS) and atherosclerosis (1, 2, 3, 4). In contrast, fats as a food components play critical roles in human diets and food science technology, especially in high fat content foods, such as mayonnaise. however, disadvantages of high fat or oil intakes to human health have been addressed. In recent decades, scientists have replaced fats in foods formulations with fat replacers based on carbohydrates,

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proteins and lipids (4). In general, one of the most common and practical methods to decrease fat contents in high fat food of fat mimetics in formulation of the products. Fat mimetics are substances which can mimic organoleptic and physical charactristics of the conventional fat molecules. In the present study, a fat replacer was designed based on the carbohydrates that contained 0-4 kilo- calories per gram to dereased fat energy, similar to ketogenic diets that are high in carbohydrates and low in fats (5).The objective of this study was to investigate how natural fat replacers based on carbohydrates were potential ingredients to study their effects on Low- fat mayonnaise formulations. Moreover, physicochemical characteristics of replacers were assessed.

## Materials and Methods

### Materials

Raw materials of low and full fat mayonnaises included: 1- sun flower (Famila, Iran), 2- salt ( Golha, Iran), 3- vinegar11 % (Varda, Iran), 4- sugar (Golha, Iran), 5- eggs (Telavang, Iran), 6-mustard powder (Tesco, Uk), 7- Xantan gum(Alpha Chemika, India) and 8- E1442(A.R.G.C, China).

**Table 1.** Formulations of low-fat and full fat mayonnaises

| | S1 | S2 25 | S3 50 | S4 75 |
|---|---|---|---|---|
| Sunflower Oil | 65 | 61.75 | 32.5 | 16.25 |
| E1442 | 0 | 1 | 2 | 3 |
| Water | 14.3 | 16.55 | 44.8 | 60.5 |
| Salt | 1.5 | | | |
| Xantan Gum | 0.2 | | | |
| Mustard powder | 0.5 | | | |
| Egg | 4 | | | |
| Sugar | 5.5 | | | |
| Vinegar 11% | 9 | | | |

*In addition, distilled water (DW) was added to all of the assays as a part of the formulation

### Mayonnaise preparation

To prepared mayonnaise samples for the physicochemical experiments, 1442, xanthan gum, sugar, water, mustard powder, vinegar and whole eggs were mixed at high speed for 3 minutes electrical blender (Model 584, Tefal, France). Then, oil was gradually added into blender and stirred at 6000 rpm for 6 min until the emulsion system was established. Ingredients were mixed at 1500 rpm for a further 5 min. All of full and low-fat mayonnaise samples at stored at 4°C until use.

### Physicochemical characteristics

Ash and moisture contents were assessed using to AOAC official methods nos 950.46 and 920.153, respectively. Moreover, fat content was assessed using Soxhlet apparatus based on AOAC official methods nos 963.15 (6,7). The pH value was assessed using pH-meter (Lutron-212, China) and acidification measurement was carried out by titration of sample with 0.1 N NaOH using the equation (1). Results were reported proportion of acetic acid%.

$$\text{Acidification based on acetic acid} = \frac{0.006 \times a \times 100}{s} \quad \text{(Eq.1)}$$

a = the volume of NaOH
s = weight of the sample

Theoretical energy of the sample was assessed by multiplying carbohydrate (CHO) and protein values with 4 kcal/g of CHO/protein and fat values with 9 Kcal/g of fats. Assessment were repeated thrice to check the repeatability.

### Color attributes

Lightness (L*), yellowness (b*) and redness (a*) indices of all mayonnaise samples were measured using Hunter Lab, (Chroma Meter Model, CR-410, Konika-Minolta, Japain). Positive and negative values of a*showed the magnitude of reddish and greenish of the samples, respectively. In addition, a positive value of b*indicate yellowish and the negative value revealed bluish of mayonnaise samples.

### Stability of the emulsion

To assess of stability of the mayonnaise samples, centrifugation was used. Double-emulsified mayonnaise sample (M0) was centrifuged at 3,913×g for 15 min using a centrifuge (Hettich Mikro 200/200R; Sigma Laborzentrifugen ,Germany). After separation of the supernatant (M1) from double-emulsified mayonnaise, the stability of the emulsion was assessed using the following formula:

$$\text{Stability of emulsion}(\%) = x = \frac{M1}{M2} \times 100 \quad \text{(Eq.2)}$$

Where M1 was the ratio of the separated part and M0 was the initial weight of the emulsion.

### Apparent viscosity analysis

Viscosity of full and low-fat mayonnaise samples was assessed using by viscometer (Visco88; Bohlin, UK) after 24 h storage at 25 ºC. Apparent viscosity was measurement at 100 $s^{-1}$ shear rate.

### Sensory analysis

In sensory evaluation, 15 professional assessors were selected. Sensory charactristics parameters that designed to this experiment were, texture, color, flavor, appearance, mouthfeel, consistency, overall acceptability and intent to purchase. Every part of these parameters was scored based on a five-point scale: 5= was the highest point and 0: the lowest point. All of the samples showed by three-digit labeling code on each sample to easy access to assessors. The assessors were instructed to rinse their mouths. All

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sessions were carried out in a sensory laboratory with separate booths. All of the samples were stored one day at room temperature (RM) (25 ºC).

### Statistical Analysis

All experiments were carried out in triplicates. Statistical analysis was carried out using IBM SPSS software v. 20.0 as well as with different statistical test such as one-way ANOVA. Results were expressed with *p*-values of carious treatments.

## Results

### Physicochemical properties

Reults of physicochemical charactristics for the full and low fat mayonaise samples shown in Table 2.

**Moisture**: All the full-fat mayonnaise samples included the higher moisture contents than that the testifier and full-fat mayonnaise included the lowest score in moisture content. Result demonstrated that low-fat samples were higher in moisture content than that the full-fat samples were.

**Fat content: S**ignificant differences ($P\leq$ 0.05) were reported between the low and full-fat mayonnaises in fat contents and full-fat samples as testifier included the highest value in this experiment.

**Calorie:** Caloric measurement of low-fat samples was significantly ($P \leq 0.05$) decreased by increasing level of substitution. In addition, full fat mayonnaise was higher in calorie index than that the low-fat sample.

**Protein**: As shown in Table 2, protein contents of low-fat mayonnaise samples included (0.68-0.73). S2 sample lowest value of protein content.

**Acid value and pH**: Results of pH and acidification are shown in Table 2. Acid value of full fat sample was higher than low fat samples. Moreover, pH value of the testifier was lower than that of low-fat mayonnaise samples with no significant differences.

**Ash and dry matter**: Low-fat mayonnaise samples included the lowest ash and dry matter contents than those the testifier did and these data were significant ($P\leq 0.05$). In low-fat sample, S4 with the highest concentration of E1442 and xantan gum included the highest quantities of ash.

**Stability of emulsion**: Results for the stability of emulsion in full and low-fat mayonnaise samples during storage (180 days) shown in Fig1. Data demonstrated that testifier samples included the lowest amount during storage. Samples with E1442 in formulation had significantly highest stability of emulsion during of storage times ($P\leq$ 0.05).

**Table 2.** Physicochemical characteristics of full and low-fat mayonnaise samples

| | pH | Acid value | Moisture | Protein | Fat | Ash | Dry matter | Calorie/K cal per 100gr |
|---|---|---|---|---|---|---|---|---|
| S1 | 3.70±0.11$^{a}$ | 1.12±0.22$^{a}$ | 24.60±0.11$^{d}$ | 0.70±0.12$^{a}$ | 67.14±0.01$^{a}$ | 0.755±0.14$^{a}$ | 74.22±0.11$^{a}$ | 630±0.11$^{a}$ |
| S2 | 3.71±0.66$^{a}$ | 1.12±0.35$^{a}$ | 38.10±0.14$^{c}$ | 0.68±0.15$^{a}$ | 54.18±0.06$^{b}$ | 0.810±0.10$^{b}$ | 59.28±0.12$^{b}$ | 550±0.13$^{b}$ |
| S3 | 3.72±0.34$^{a}$ | 1.13±0.38$^{a}$ | 53.50±0.17$^{b}$ | 0.72±0.25$^{b}$ | 36.18±0.07$^{c}$ | 0.829±0.08$^{c}$ | 44.36±0.14$^{c}$ | 387±0.24$^{c}$ |
| S4 | 3.73±0.78$^{a}$ | 1.13±0.54$^{a}$ | 69.90±0.16$^{a}$ | 0.73±0.33$^{b}$ | 24.15±0.09$^{d}$ | 0.849±0.11$^{d}$ | 29.69±0.16$^{d}$ | 277±0.22$^{d}$ |

Note: Values are reported as Mean± standard deviation.

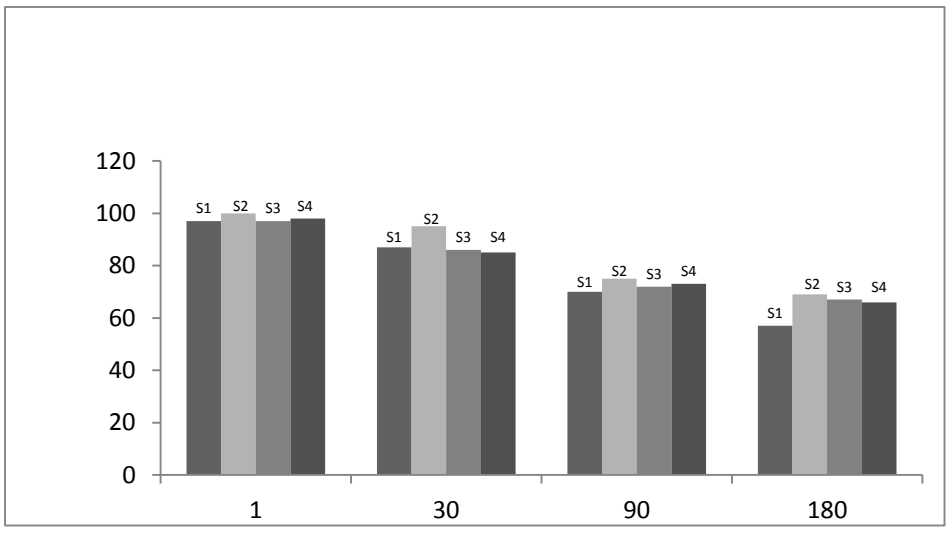



**Figure1.** Stability of full and low-fat mayonnaise samples during storage (180 days)

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### Color attributes

Results for the color attributes of the samples are shown in Table 3. No significance different ($P$ >0.05) were detected between the low and full-fat mayonnaises in lightness. The L* value of the sample prepared with 0.75% of E1442 was higher in the current study. The highest a* value was observed in the control with no significant differences between the control and low-fat sample. Moreover, b* value of full-fat sample was higher than low-fat sample.

**Table 3.**Color attributes of full and low-fat mayonnaise samples

| | L* | a* | b* |
|---|---|---|---|
| S1 | 84.20±0.11[a] | 11.54±0.35[a] | -2.30±0.25[a] |
| S2 | 84.25±0.20[a] | 10.24±0.36[a] | -2.10±0.35[a] |
| S3 | 84.28±0.14[a] | 9.87±0.98[b] | -2.05±0.39[a] |
| S4 | 83.24±0.15[a] | 10.07±0.52[a] | -2.17±0.66[a] |

### Viscosity measurement

Apparent viscosity results of the full low-fat mayonnaise samples are shown in Fig 2. Full fat mayonnaise sample included the lowest value of apparent viscosity. Increasing quantity of the substitution of E1442 directly affected apparent viscosity in low-fat mayonnaise sample with significance ($P$ ≤0.05). Apparent viscosity increased by increasing levels of fat replacers (E1442).

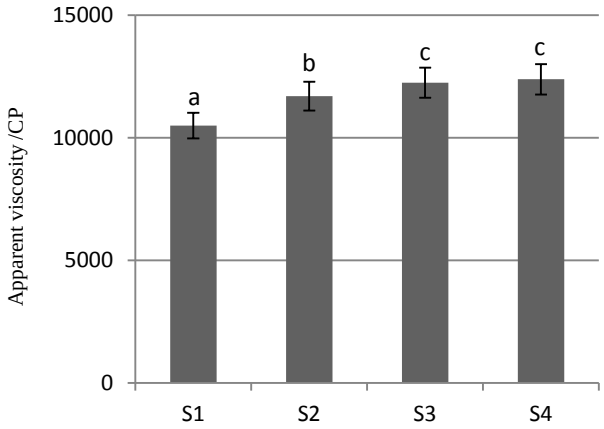



**Figure 2.** Apparent viscosity of full t and low-fat mayonnaise samples

### Sensory characteristics

Sensory attributes of the samples shown in Table 4. Data analysis in sensory evaluation revealed that S1 sample included higher than some of parameters in sensory characteristics assessment such as intent to purchase and overall acceptability and this comparison wasn't significant, compared to the full-fat sample ($P$≤ 0.05).

## Discussion

In this study, increased moisture content could be attributed to: quantity of water in the formulation (water molecules bond with hydrogen groups) and use and overlap of two kinds of fat replacer and thickening agent such as xantan gum and E1442 as fat replacers in low fat formulations with hydroxyl groups in their structures based on the carbohydrates. The fat content of full-fat mayonnaise was higher than that of low-fat sample. The authors concluded the, phenomenon was attributed to substitution of oil in low-fat samples by fat replacers and water to prepared low fat mayonnaise. In addition, the present results of fat content were similar to those of others (4, 9). Calorie assessment is directly linked to fat content. In analysis, each per gram of fat included 9 kcal/g and this value of calorie was substituted with fat replacer of carbohydrates with 4 kcal or less (modified starch by acid, hydrolysis, oxidation and crosslinking included 4 kcal/g). Therefore, low-fat samples were appropriate diets. It seems that the, original source of proteins in traditional mayonnaises included whole eggs or yolks and this ingredient did not change in the samples, based on formulation. These results were similar to those from other studies. Amin et al.,(2014) reported no significance differences ($P$ > 0.05) between the full and the low-fat mayonnaises based on their proteins. This might be due to the constant ingredients types and levels in all formulations, except oil, water and fat replacers in formulations. In addition, it is clear that, fat replacers in the present study to prepared low-fat mayonnaise included a little quantity of various of proteins in their molecule structures. Acidification and power of hydrogen are important contaminations in various sauces and dressing.

**Table 4.** Sensory evaluations of full and low fat mayonnaise samples

| | Color | Appearance | Taste | Texture | Mouth feel | Consistency | Overall acceptability | Intent to purchase |
|---|---|---|---|---|---|---|---|---|
| S1 | 4.44±0.11[b] | 4.55±0.25[b] | 4.60±0.26[a] | 4.71±0.55[a] | 4.77±0.58[a] | 4.79±0.78[a] | 4.75±0.98[b] | 4.80±0.33[a] |
| S2 | 4.58±0.26[a] | 4.59±0.14[a] | 4.58±0.97[a] | 4.70±0.66[a] | 4.55±0.40[b] | 4.80±0.24[a] | 4.78±0.55[a] | 4.81±0.47[a] |
| S3 | 4.35±0.27[c] | 4.51±0.90[c] | 4.47±0.87[b] | 4.30±0.84[b] | 4.50±0.22[c] | 4.66±0.24[b] | 4.33±0.87[c] | 4.60±0.75[b] |
| S4 | 4.30±0.49[d] | 4.33±0.57[d] | 4.39±0.07[c] | 4.20±0.36[c] | 4.39±0.11[c] | 4.57±0.36[c] | 4.30±0.80[d] | 4.29±0.50[c] |

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Researchers reported that pH value of full and low-fat mayonnaises should be 4.1 or less to preserve products free from Salmonella *spp*. Based on the human health, it is noteworthy notice that pH values of the mayonnaises in the current study ranged from 3.34 to 3.38 (10, 4). Both of these factors (acidification and pH) increased in low-fat mayonnaise samples. It seemed that, there were bilateral relationship between some of physicochemical characteristics in O/W emulsions such as power of hydrogen and acidification. In pH and acid values, it seemed that: pH 3.9 was the isoelectric point of egg yolks and added salt at mayonnaise formulations reclaiming the isoelectric point for pH. Furthermore, Extra quantities of salt in the formulations caused the egg yolk proteins to aggregate and dilatation of acetic acid in continuous phase system. In addition, water contents in vinegar at various quantities in formulation caused growth of lactic acid bacteria (LAB) in the aqueous phase system. These results were similar to those of other studies (Amin et al,. 2014, Hosseinvand and sohrabvandi, 2016) (8, 9). Clearly, this might be due to the fat replacers of carbohydrates as dietary fibers included phytochemicals, mineral-components and macro-nutrients. In structure of various kinds of modified starch, there are a wide number of glucose and branches with liner molecules such as amylose and amylopectin. Thus, this component increases ash and dry matter in various food formulations. In the current study, the results were similar to the results of study by Khalid et al., 2020, Who reported that low fat sample is testifier in ash content in full fat mayonnaise sauce without any fat replacers based on carbohydrate (10). Consumers usually look for sauces with the highest satiability in structure during consumption. In food chemistry, it is noteworthy that parts of ingredients such as oils, eggs and filling agents of fat replacers and gums affect the stability of the emulsions. Clearly, egg yolk in mayonnaise formulation includes outstanding positive effects on the structure and stability of emulsion. It seems that, some chemical action and interaction occur in structure of mayonnaise emulsion and effect on the stability of emulsion system such as; 1) Interaction and steric repulsion between polar and non-polar groups as, proteins are polar groups such as eggs in formulation of mayonnaise; 2) egg yolk includes multiple use as a complex structure, especially with lecithin and lipovitellin with flocculation abilities; 3) Van der Walls attraction balances between the forces (attraction and repulsion); 4) modified starch (E1442) with ability of gelatinization during pasteurization process includes capacity to act as an emulsifier its to the ability to absorb in oil-water interface; and 5) xantan gum as one of the common polysaccharides in food science is stable polydisperse macromolecules with majorly hydrophilic characteristics (11,12). Liu et al., stated that decreas of the droplet diameter led to a greater contact surface area between the droplets, and therefore to increased viscosity, which resulted in a further stable emulsion (13). Color parameters in foods and agricultural products affect palatability, consumption and global marketing. Lightness of mayonnaise plays important roles by the consumers. In addition colors of E1442 and xantan gum as raw materials were white as one of the major reasons of lightness. To expand this phenomenon three reasons are ascribed 1) in an oil-in-water emulsion system, creaming of an emulsion is sometimes observed, which indicates higher levels of dispersed oil phase in the top layer of the emulsion; 2) changes in dispersed phase globule diameter size; 3) quantinty of water in food formulations affect directly birefringence of the starch granules (14). Moreover, quantity of liquids (water to hydration of xantan gum and E1442 with vinegar) in low-fat mayonnaise samples was starch swelling and birefringence. In the present study, lightness of the samples, decreased by increasing E1442 concentration; similar results to other study. Authors, reported that low-fat mustard sauce lightness decreased by increasing levels of beta-glucan as a fat replacer in low fat mustard sauce formulation (4). Low-fat samples was prepared with E1442 included the highest score, compared to testifier did. It can be stated that one of the most important affect based on increasing apparent viscosity in low fat sample was gelatinization of starch. In addition, they addressed some justifications for understanding this phenomenon, including; 1) modified starch prepared with phosphate a great ability, compared to another modified starch to enhance rheological parameters such as storage module and mathematical methods such as $R^2$, yield stress and shear rate units; 2) overlap by high weight molecules such as xantan gum with starch (E1442) based on synergistic interactions in the aqueous phase system in low fat mayonnaise formulation; 3) source of the starch grain such as maize, corn and plants as well as, ratio of the amylose and amylopectin contents in starch molecules is one of the leading reasons in recent scientific references (14,15); and 4) depending on the heating processing (pasteurization in this study) and molecular diameter size, dispersion system (starch granules with water) exist in formulation of low-fat mayonnaises and viscosity of low fat sample increases, compared to the testifier (16). Previous studies have reported that low-fat mayonnaise samples prepared with various starch origin were better than the control samples in rheological behaviors, especially apparent viscosity (16, 18, 19). Based on the sensory evaluations, the low-fat mayonnaise sample made with 1% of E1442 (S1) included the highest score of appearance. Palatability and sensory evaluation are important characteristics of the final products in food marketing. The best score in texture belonged to low-fat mayonnaise prepared with fat replacer at 1% (S2) It seemed that gelatinization of starch in the aqueous phase system was outstanding and bold reason to this phenomenon.

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Moreover, samples of low fat mayonnaise at 2 and 3% of E1442 in the formulation showed the worst scores in some parameters such as color and taste and based on opinion of panel members were unacceptable samples in this study. Finally, sensory attributes, the current authors, stated that low-fat mayonnaises prepared with sunflower oil and modified rice starch were best rated by consumers (20). In addition, addition of E1442 as modified starch affected color of the low-fat sample, especially after heating processes, such as pasteurization and sterilization. These results were similar to those by Subroto et al, 2020, who reported that of heat-moisture treatment (HMT) potato starch affected color of the ketchup samples as the color faded by increasing of the concentration (21).

**Conclusion**

The aim of this study to preparing of low-fat mayonnaises with xantan gum in the main formulation, replaced by E1442 in traditional mayonnaises. In general, results showed that fat content of full-fat mayonnaises could decrease from 65% (testifier) to 61.75% as the best sample by combination of xantan gum and E1442 in low-fat mayonnaise formulations. Nevertheless, low-fat samples with 0.255% of E1442 and 0.2% of xantan gum (w/v%) contributed to highest scores such as emulsion stability, as well as sensory characteristics such as overall acceptability and intent to purchase. In addition, parameters such as calorie, dry matter and fat content in low-fat samples decreased with increases in E1442 levels in the formulation. Thus, E1442 with xantan gum in low-fat mayonnaises can be added to successfully substitute a proportion fats in mayonnaise production with no alternations in mayonnaise physicochemical and sensory characteristics.

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